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CHANGES IN REGIONAL TRAVEL CHARACTERISTICS IN THE

SAN FRANCISCO BAY AREA: 1960-1981

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ABSTRACT

This paper reports the results of updating a travel survey in the nine-county San Francisco Bay Region. It compares trip-making characteristics of the 1965 Home Interview Survey with those of the 1981 Telephone Survey. The comparison is complemented with work-trip modal shares from the 1960, 1970, and 1980 Census journey-to-work data. The observed changes in travel habits are traced to changes in demographic and economic characteristics in the region. Household trip rates are summarized by trip purpose, mode of travel, household size, auto ownership, income, and housing structure type. The significance of the changes in trip rates is assessed intuitively and verified by simple statistical tests. The comparative analysis shows that the total household trip rates are stable over long periods of time. However, there are significant shifts in the frequency of trip-making by trip purpose: Households make less home-based shopping/personal business, and more non-home-based trips now relative to 1965. Although some trip rates by socio-economic stratifications are significantly different in the two surveys, the overall effect on aggregate regional rates are tempered by shifts in the distribution of households by socio-economic stratifications. Regional transit shares for work trips were found to be on the decline between 1960 and 1970, and were constant between 1970 and 1980. For those urban counties where significant transit service improvement took place between 1970 and 1980, transit work-trip shares increased significantly. Public transportation appears to be absorbing more of the non-work trip market now relative to 1965.



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1.0 INTRODUCTION

The purpose of this paper is to report an update of a travel survey and to investigate changes in trip characteristics since 1965 in the San Francisco Bay Region. This update was done in 1981 using a relatively small-sample telephone survey of about 7,100 households. The earlier Home Interview Survey was conducted in 1965 and consisted of about 30,000 households. The survey results are corroborated by and complemented with the 1960, 1970, and 1980 Census journey-to-work data. The changes in travel characteristics are traced to changes in demographic, economic, and car ownership variables.

Updating travel data for use in transportation planning has been a subject of much concern in the decades of the 1970s and the 1980s. In this era of fiscal constraints, planners and researchers have questioned the undertaking of large scale home interview surveys similar to those of the 1950s and the 1960s. At the same time, an equally important concern has been the use of old travel data in travel demand model development, travel forecasting, and in the day-to-day activities of metropolitan planning organizations (MPO's).

The concept of small-sample surveys grew not only out of financial necessity, but had popularity due to advances in travel demand model development. A new breed of models was in the research stages and in limited application in the early 1970s (1, 2, 3). These "disaggregate behavioral" models require a small sample of households, trip makers, and trip observations for their estimation. In the San Francisco Bay Area, it was found that their application in the traditional urban travel fore-

casting process requires aggregate validation (4, 5). Furthermore, their transferability from one urban area to another hinges upon a recent base year disaggregate and aggregate adaptation where model coefficients are re-estimated/adjusted to replicate known or estimated trip patterns (6).

The introduction of the journey-to-work questions in the 1970 and the 1980 Census of population and housing provided a valuable complement to the regional travel data bases in metropolitan areas. However, a gap still remained unfilled with regard to the need for updating the non-work travel data. It was with this realization that the San Francisco Bay Area Metropolitan Transportation Commission (MTC) embarked on its 1981 small-sample survey (7) to complement the 1980 Urban Transportation Planning Package (UTPP) data for work trips and to update the 1965 Survey.

The 1965 Survey was expanded by MTC in 1976 using updated estimates of socio-economic variables. The expansion was to total households by housing structure type and 290 zones. The sample included about 20,500 households and their weekday trips.

The 1981 Household Travel Survey was a telephone survey of 7,091 households selected disproportionately throughout the region. About one-half of the surveyed households were residents of San Francisco County, at a sampling rate of 1.2%. The other eight counties had a sampling rate of 0.22%. Beyond this sample control total, households were selected by using telephone directory-based random digit dialing in such a way that unlisted households could be selected. The weekday component of the sample was 6,209 households. This weekday sample was weighted to the 1980 Census count of households by three household-size groups and 45

districts of residence. Trip expansion combined household weighting with minor adjustment factors for missing trip data (8).

Any changes that are discerned from a comparative analysis of this type are bound to be colored by inherent biases in the data. These biases arise due to incompatible definitions, unrepresentative samples, different survey instruments/data collection methods, data preparation approaches, and otherwise imprecise data base estimates. A special effort was made in the present analysis to prepare and report data that is as compatible as possible. For the 1965 data, the files were re-processed using the same trip purpose and mode aggregations as those used in the 1981 Survey. We proceed in the balance of this paper as though the data base is solid and representative. However, this may not be the case and the readers are forewarned about such issues. A number of points should be kept in mind as the comparisons are made and generalizations drawn. First, the 1981 Survey had a small sample carefully selected and with a follow-up for non-response. In contrast, the 1965 sample was much larger but had about 45% non-response/incomplete interviews, and without any follow-up. Second, the 1981 survey preparation was more carefully conducted than the 1965 Survey. Sample expansion used more behavioral stratifications. The 1981 Survey had a better Census sample frame to expand to, relative to 1965. Third, the Census journey-to-work data is based on reported travel for the most frequent work trip location and mode for the week prior to April 1 of the Census year. Survey trips are the actual weekday trips made by the respondents.

The regional travel patterns are, to a large extent, dependent on demographic-economic characteristics. Therefore, any investigation of

changes in travel has to take into consideration the changes over time in such variables as household size, household income, employed per household, and car ownership. Reported here are regional data summarized from Bureau of the Census tapes and reports, estimates of the Association of Bay Area Governments (ABAG), and from household travel surveys conducted in the region. These are used for interpreting changes in trip characteristics. The summary data place the changes in trip-making into a demographic-economic context and shed some light on the possible biases regarding representation of these variables in the surveys.

The San Francisco Bay Region consists of nine counties surrounding the Bay. About five million people and two million households live in this vast region of four and one-half million acres. About two and one-half million jobs provide employment opportunities for its residents (9).

Table 1 shows a summary of aggregate regional growth from 1960 to 1980. Between 1960 and 1970, the growth was 27% in total population, 32% in the number of households, 31% in employed residents, 53% in total school enrollments (ages 3 to 34), 149% in college enrollments, and 27% in kindergarten and elementary school (grades 1-8) enrollments. The decade of the seventies recorded a growth of 12% in total population, 27% in the number of households, 36% in employed residents, 6% in total school enrollments, 81% in college enrollments, and -18% in kindergarten and elementary school enrollments. The decline over time in household size is evident from Table 1. This is accompanied by an increase in the number of employed/HH, income/HH, drivers/HH, and cars per household. These are important variables which influence regional travel in the aggregate and by market segment.

TABLE 1
COMPARATIVE REGIONAL DEMOGRAPHIC AND ECONOMIC CHARACTERISTICS
1960 TO 1980

Variable	1960 CENSUS	1965 (ABAG)	1965 BATSC SURVEY	1970 CENSUS	1980 CENSUS	1980/ 1981 SURVEY
Total Population	3,639	4,216		4,628	5,180	
Pop. in Households	3,515	4,106	4,331	4,501	5,059	5,051
Households	1,174	1,387	1,387	1,553	1,971	1,970
Employed Residents	1,433	1,664	1,697	1,882	2,555	2,639
Total Jobs (in 1000's)		1,664			2,537*	2,733
Total School Enroll.	904			1,380	1,464	
Enrollments in K, G1-8	616			782	642	
Enroll. in High Schools	195			326	333	
Enroll. in Colleges (in 1000's)	93			232	419	
Households With No Cars	232		189	246	241	214
Households With 1 Car	624		617	688	706	683
Households With 2 Cars	279		466	511	642	711
Households With 3+ Cars (in 1000's)	39		115	107	382	362
Mean Household Income		\$9,353	\$9,592	\$11,251	\$24,350	\$26,517
Household Size	2.99	2.96	3.12	2.90	2.57	2.56
Employed/Household	1.22	1.20	1.22	1.21	1.30	1.34
Drivers/Household			1.67			1.75
Autos/Household	1.12		1.40	1.33	1.68	1.70
% Households w/no Cars	20%		14%	16%	12%	11%
% Households w/1 Car	53%		44%	44%	36%	35%
% Households w/2 Cars	24%		34%	33%	33%	36%
% Households w/3+ Cars	3%		8%	7%	19%	18%

*ABAG estimate.

2.0 CHANGES IN REGIONAL HOUSEHOLD TRIP RATES, 1965 - 1981

A comparative analysis is undertaken here for trip rates by trip purpose, mode of travel, and household stratifications commonly used in travel analyses. The definitions of trip purposes and modes follow the traditional jargon. Home-based Work (HBW) trips are those to/from work and work-related business. Home-based Shop (HBSH) is a catchall category which includes shopping, personal business, and "other" trip purposes. "Person" mode is the summation of vehicle driver, vehicle passenger and transit passenger. Mode "other" includes motorcycle, moped, and bicycle trips.

It should be noted that data used in this paper is taken from an array of Census reports, MTC reports, and special tabulations. Reference (10) contains most of the 1981 Survey data cited. The 1965 data is in special tabulations recently completed by MTC staff.

Before we discuss the specifics of the comparison, we should stress the importance of household trip rates as prime determinants of total travel in transportation planning. Any changes in the rates from past surveys are of prime concern to transportation analysts. Such changes are not only important for updating trip generation models, but are also used in micro-analyses in subarea and facility planning.

2.1 Household Trip Rates by Purpose and Mode

The comparison between 1965 and 1981 trip rates is shown in Table 2 by trip purpose and mode. Overall, total trips per household decreased about 1%. This small change suggests that the effect of energy shortages in 1973 and 1979 on trip making have stabilized.

TABLE 2
COMPARATIVE TRIPS PER HOUSEHOLD BY PURPOSE AND MODE
1965 VS. 1981 REGIONAL WEEKDAY TRIPS

Mode	Home-Based			School	Non-Home-Based	Total
	Work	Shop	Soc/Rec			
Vehicle Driver	1.287	1.599	.505	.106	1.037	4.534
	1.380	1.583	.585	.173	1.510	5.231
	7%	1%	16%	63%	46%	15%
In-Vehicle Person	1.518	2.307	.915	.295	1.499	6.535
	1.558	1.964	1.011	.387	1.894	6.814
	3%	-15%	10%	31%	26%	4%
Transit	.220	.085	.035	.086	.060	.486
	.206	.085	.044	.126	.097	.558
	-6%	0	26%	47%	62%	15%
Person (In-Vehicle Person plus Transit)	1.738	2.393	.950	.381	1.559	7.021
	1.764	2.049	1.056	.513	1.990	7.372
	1%	-14%	11%	35%	28%	5%
School Bus				.146		.146
				.089		.089
				-39%		-39%
Walk	.090	.286	.177	.514	.281	1.348
	.076	.188	.143	.285	.303	.995
	-16%	-34%	-19%	-45%	8%	-26%
Other	.031	.053	.057	.057	.065	.263
	.050	.037	.063	.065	.042	.257
	61%	-30%	11%	14%	-35%	-2%
Total	1.858	2.732	1.184	1.097	1.906	8.777
	1.89	2.274	1.262	.952	2.335	8.713
	2%	-17%	7%	-13%	23%	-1%

Notes: Upper entry is the 1965 trip rate. Middle entry is the 1981 trip rate. Lower entry is the percent change.

By trip purpose, the change in trip rates ranges between -17% for home-based shop and +23% for non-home-based. Work trip rates increase by 2%, social/recreation trip rates increase by 7%, and school trips decrease by 13%. The increase in work trip rates is insignificant. The decrease in school trips is traced to drops in school enrollments for kindergarten and elementary school grades 1-8. A comparison of the 1970 and 1980 Census school enrollments for these grades shows that the decrease in enrollments was about 18%. This is a symptom of the demographic changes in the household composition of the last decade. (See Table 1 for changes in household size and school enrollments.)

A significant change appears to have occurred in travel behavior between 1965 and 1981. Household members have switched their travel habits from home-based shopping trips to non-home-based trips. This change is interpreted intuitively as a response to increases in travel costs and gasoline shortages of the last decade. It appears that households have switched from their frequent home to shop and personal business activities to combining their chores into multi-leg tours, thus increasing the number of non-home-based trips.

By mode, the range of variation in trip rates is between -39% for school bus passengers and +15% for transit passengers and vehicle drivers. Person trips increase 5% and walk trips decrease by 26%. The decrease in walk trips is universal over all trip purposes: although the NHB walk increases by 8%, its share of total NHB drops from 15% to 13%. The largest drop in walk trip rates is in the school trip purpose. This is due to the drop in enrollments for kindergarten and elementary schools mentioned above. It is reasonable

to assume that walk to school is largely a market for students in grades K-8, and therefore a drop in such enrollments will cause a drop in walk to school. The changes in the walk mode for other trip purposes appears to be symptomatic of more multi-leg tours where the walk mode can't compete with other modes for such a diversified market of trip purposes. The substantial change in school bus passenger mode is due to the passage of the 1978 Proposition 13 in California. This change in real property taxation yielded major reductions in local government revenues, including school bus programs. The slack was taken by higher patronage for auto and public transportation.

A number of studies (11, 12, 13, 14) have addressed the stability of trip frequency, trip generation models, and travel time characteristics. A few of these studies (11, 12) present trip rate data comparable to those reported here. Furthermore, their comparison is for a much earlier time span before the 1973 and 1979 gasoline shortages. Seven U.S. cities studied by an ITE Committee (11) show an average increase from 6.5 to 7.7 "person" trips per household. This 18% increase over an average period of 12.4 years is in contrast to ours of 5% (7.021 to 7.372) over a period of 16 years. Based on this comparison, it appears that the energy shortages of the 1970s have moderated the increases in trip rates.

2.2 Household Trip Rates by Household Size

In travel forecasting, trips are sometimes generated by household size. Alternatively, some travel demand models incorporate average

household size as an explanatory variable in linear regression models. The average effect of household size on trip making is assessed here by analyzing trips per household by household size shown in Table 3. Trips per person can also be computed but the percent change will be the same.

For total trips, all household size groups experience an increase in trips per household. However, the average household trip rate remains unchanged. This is due to the fact that there is a major shift in the regional distribution of households by household size shown in Table 3. We now have a much larger proportion of households in the one-person group, and much less in the five-and-over-person group. This is supported not only by the two surveys but by the 1970 and 1980 Censuses as well.

For work trips, the small household-size groups experience little change in trips/household. As household size increases, the change in trips/household increases. This is due to the fact that larger households have a higher number of employed now compared with 1965.

For shopping trips, all households experience a drop in trips except for the one-person group. For the balance of the trip purposes, all household-size groups increase their trip making. However, the net effect on school trips is a reduction in the regional trip rate. This is also due to changes in the regional distribution of households by household size.

2.3 Household Trip Rates by Auto Ownership

Auto ownership is an important household characteristic which determines mobility and trip making. Table 4 gives a comparison of

TABLE 3
COMPARATIVE TRIPS PER HOUSEHOLD BY HOUSEHOLD SIZE
1965 VS. 1981 REGIONAL WEEKDAY TRIPS

House- hold Size	Percent House- holds	Home-Based				Non- Home- Based	Total
		Work	Shop	Soc/Rec	School		
1 Person	15%	0.883	0.903	0.523	0.060	0.966	3.335
	26%	0.889	0.966	0.622	0.086	1.390	3.953
		1%	7%	19%	43%	44%	19%
2 Persons	30%	1.734	1.874	0.823	0.164	1.574	6.169
	33%	1.767	1.868	1.075	0.267	2.103	7.079
		2%	0%	31%	63%	34%	15%
3 Persons	18%	2.137	2.618	1.104	0.762	1.821	8.443
	16%	2.262	2.539	1.310	0.937	2.598	9.646
		6%	-3%	19%	23%	43%	14%
4 Persons	17%	2.193	3.666	1.479	1.613	2.358	11.309
	15%	2.646	3.612	1.896	2.087	3.293	13.533
		21%	-1%	28%	29%	40%	20%
5+ Persons	20%	2.273	4.796	2.083	3.220	2.849	15.222
	10%	3.183	4.585	2.506	3.729	3.715	17.717
		40%	-4%	20%	16%	30%	16%
All House- holds	100%	1.858	2.732	1.184	1.098	1.906	8.778
	100%	1.890	2.274	1.262	0.952	2.335	8.713
		2%	-17%	7%	-13%	23%	-1%

Notes: Upper entry is the 1965 trips/household. Middle entry is the 1981 trips/household. Lower entry is the percent change.

trips per household by auto ownership group. As can be seen, household trip rates increase as auto ownership increases. This is due, in part, to the high correlation between autos owned and household size. The changes are minimal for total trips except for the one- and two-auto households.

For work trips, there is a decrease in trips per household for the zero and one-car owners. This is balanced by an increase for the four-and-over-auto group. These shifts can be interpreted as symptoms of the high unemployment in 1981 relative to 1965 for the low auto ownership group.

For shopping trips, the reduction in the rates is in contrast to the increase in non-home-based rates as seen earlier. This holds true for most auto-ownership groups.

For social/recreation trips, there are modest decreases in the trip rates for households who own cars, in contrast to the increase for those who don't own cars. The increase can be inferred from the increase in the number of old/retired households who have more leisure time. This group also increased its transit share for social recreation from 20% in 1965 to 27% in 1981.

School trip rates drop for the medium auto-ownership groups and rise for the high auto-ownership group. The reduction is due to a drop in walk and school bus passengers more than the auto modes. The increase in the high auto-ownership trip rate is due to increased college enrollments which is related more to the auto mode than other modes.

TABLE 4
COMPARATIVE TRIPS PER HOUSEHOLD BY AUTO OWNERSHIP
1965 VS. 1981 REGIONAL WEEKDAY TRIPS

Auto Owner- Ship	Percent House- holds	Home-Based				Non- Home- Based	Total
		Work	Shop	Soc/Rec	School		
No Auto	14%	0.940	1.139	0.562	0.493	0.778	3.912
	11%	0.724	1.159	0.629	0.541	0.942	3.996
		-23%	2%	12%	10%	21%	2%
1 Auto	44%	1.669	2.430	1.022	0.891	1.606	7.618
	35%	1.298	1.738	0.974	0.577	1.713	6.301
		-22%	-28%	-5%	-35%	7%	-17%
2 Autos	34%	2.233	3.452	1.469	1.488	2.471	11.113
	36%	2.211	2.661	1.412	1.062	2.754	10.101
		-1%	-23%	-4%	-29%	11%	-9%
3 Autos	6%	2.782	3.992	1.905	1.616	2.979	13.274
	12%	2.789	3.246	1.827	1.600	3.314	12.776
		0%	-19%	-4%	-1%	11%	-4%
4+ Autos	2%	3.214	4.291	2.002	1.647	3.509	14.663
	6%	3.684	3.054	2.008	1.880	3.954	14.580
		15%	-29%	0%	14%	13%	-1%
All House- holds	100%	1.858	2.731	1.184	1.097	1.906	8.777
	100%	1.890	2.274	1.262	0.952	2.335	8.713
		2%	-17%	7%	-13%	23%	-1%

Notes: Upper entry is the 1965 trip rate. Middle entry is the 1981 trip rate. Lower entry is the percent change.

2.4 Household Trip Rates by Housing Structure Type

Housing structure type has been used in many travel demand analyses as a stratification for trip generation. It is a surrogate variable for household size, income, and auto ownership. With the changes occurring in household preferences, prompted by high costs of housing, there are some questions regarding the use of this variable in place of more behavioral variables it purports to represent. The increase in apartment conversion to condominiums and the introduction of townhouse developments has provided opportunities for a change in household composition of those families who choose to or are forced to occupy multi-family structures. Condominiums and townhouses are used nowadays by wealthy households and households of medium size. Their trip making characteristics may not coincide with apartment dwellers. Therefore, an investigation of their trip characteristics is in order.

Table 5 gives a comparison of household trip rates by housing structure type and the changes that have occurred. For condominiums and townhouses, the trip rates given are from the 1981 Survey only, since they were not reported in the 1965 Survey. As can be seen, condo and townhouse dwellers have higher total trip rates than apartment dwellers, lower rates than single family dwellers, and rates close to duplex dwellers.

The change between 1965 and 1981 for single family structure type is very small for total trips. Home-based work trip rates increase by 8% due to increases in employed per household. Home-based shopping trip rates decrease and non-home-based increase. Social/recreation

TABLE 5
COMPARATIVE TRIPS PER HOUSEHOLD BY HOUSING STRUCTURE TYPE
1965 VS. 1981 REGIONAL WEEKDAY TRIPS

Housing Structure Type	Percent House- holds	Home-Based				Non- Home- Based	Total
		Work	Shop	Soc/Rec	School		
Single Family	66%	1.978	3.257	1.353	1.380	2.164	10.131
	64%	2.134	2.727	1.467	1.230	2.639	10.196
		8%	-16%	8%	-11%	22%	1%
Condomin- iums or Town- houses	0%	N/A	N/A	N/A	N/A	N/A	N/A
	5%	1.924	1.807	1.148	0.454	2.339	7.672
		N/A	N/A	N/A	N/A	N/A	N/A
Duplex	8%	1.713	2.068	0.930	0.778	1.377	6.866
	6%	1.665	1.902	1.131	0.626	2.038	7.362
		-3%	-8%	22%	-20%	48%	7%
Apartment	26%	1.632	1.667	0.861	0.509	1.459	6.128
	25%	1.428	1.411	0.809	0.521	1.667	5.835
		-12%	-15%	-6%	2%	14%	-5%
All	100%	1.859	2.731	1.184	1.097	1.906	8.778
	100%	1.890	2.274	1.262	0.952	2.335	8.713
		2%	-17%	7%	-13%	23%	-1%

Notes: Upper entry is the 1965 trip rate. Middle entry is the 1981 trip rate. Lower entry is the percent change.

trips increase and school trips decrease. All these changes are manifestations of the phenomena observed earlier.

Apartment dwellers decrease their trip-making rates for work and total trips more than any other housing structure type. The drop in work trips is attributed to higher unemployment in 1981 relative to 1965. The drop in social/recreation trips is a sign of the hard economic times the region is experiencing. The increase in school trips is small and is attributed to larger households (with children) shifting to apartment housing.

2.5 Household Trip Rates by Income

Household income continues to be a significant variable in determining trip-making characteristics. Comparative trip rates between 1965 and 1981 are shown in Table 6 by income group. The low, medium, and high groups are defined by selecting households from the two surveys to form approximately equal proportions based on the income distribution of households in the two surveys.

The data shows that total household trip rates have dropped by about 4% for the medium income group. For the high income group, total trip rates have increased by 3%. Work trips are down by 6% for the low income group and are stable for the medium income group. Work trips for the high income group have increased by 11%, an indication of an increase in employed per household. Shopping trip rates are down significantly for all groups except for those households that refused to report their income. Social/recreation trip rates have not changed for the medium income group, but have increased 7% and

TABLE 6
COMPARATIVE TRIPS PER HOUSEHOLD BY INCOME
1965 VS. 1981 REGIONAL WEEKDAY TRIPS

Income Group	Home-Based				Non-Home-Based	Total
	Work	Shop	Soc/Rec	School		
Low	1.067	2.003	0.895	0.713	1.248	5.925
	1.004	1.829	0.958	0.677	1.524	5.992
	-6%	-9%	7%	-5%	22%	1%
Medium	1.971	3.030	1.292	1.174	1.951	9.418
	2.018	2.333	1.291	0.984	2.432	9.058
	2%	-23%	0	-16%	25%	-4%
High	2.490	3.419	1.521	1.396	2.764	11.590
	2.772	2.795	1.668	1.228	3.422	11.886
	11%	-18%	10%	-12%	24%	3%
Income Not Reported	1.633	1.913	0.753	0.960	1.145	6.403
	1.594	2.022	1.030	0.869	1.692	7.207
	-2%	6%	37%	-9%	48%	13%
All	1.858	2.731	1.184	1.097	1.906	8.777
	1.890	2.274	1.262	0.952	2.335	8.713
	2%	-17%	7%	-13%	23%	-1%

Notes: Upper entry is the 1965 trips/household. Middle entry is the 1981 trips/household. Lower entry is the percent change.

1965 low income is 0-\$6,000 (29% of households). Medium income is \$6,000-\$10,000 (36% of households). High income is \$10,000 and over (35% of households).

1981 low income is 0-\$15,000 (31% of households). Medium income is \$15,000-\$30,000 (36% of households). High income is \$30,000 and over (33% of households).

10% for low and high income, respectively. School trip rates decreased across the board and non-home-based increased significantly.

2.6 Statistical Tests of Significance for Changes in Trip Rates

Differences between 1965 and 1981 trip rates per household were assessed in the previous sections of this paper by inspecting the percentage changes by trip purpose and mode for the two surveys. Intuitive judgments and interpretations were made by analyzing the changes in demographic and economic variables over the same period of time. In contrast, the statistical measures associated with the trip rates are summarized in Tables 7 and 8 for selected trip purposes, modes, and household stratifications. Sample means, standard deviations, and standard error of the means are calculated. These sample descriptors are estimates of the true population statistics. The standard error of the mean is the standard deviation of the sampling distribution of the mean trip rates. Confidence intervals around the means were established at the 0.05 level for a two-tailed test. Standard errors of the difference between means were estimated manually. A t-statistic for the difference between sample means was constructed using standard statistical formulae (15). The above assumes random independent samples which have a "normal" sampling distribution of the mean trip rates. The judgment about the significance of the differences between 1965 and 1981 trip rates is based on the computed and tabled t statistics. When the computed t is greater than 1.960 (table t at .05 level), we reject the null hypothesis that the two means are equal. Therefore, the "significant difference" is labeled "yes." If the computed t is less than 1.96,

we fail to reject the null hypothesis that the two means are equal. Therefore, the significant difference is labeled "no."

The summary statistics of Tables 7 and 8 suggest that total trips and home-based work trips per household from the two surveys are not significantly different. The other trip purposes are. Trip rates per person are significantly different for all trip purposes except home-based shopping. This shows the effect of changes in household size on household trip rates. By mode, the trip rate per household and per person are significantly different for the drivers, the in-vehicle person, the transit, and the person mode. By household socio-economic stratifiers, various degrees of significance in the differences between means are listed. There are borderline cases where the computed t is close to 1.96 and, therefore, the judgment on significant difference should be read in conjunction with the value of the t score.

The comparison between the statistical tests performed here and the percentage changes reported earlier shows that changes in total trip rates (by purpose or mode) of 5% and over can be considered significant. Changes of less than 5% are insignificant. This inferred rule-of-thumb is violated by households living in duplexes who have a 7% change in total trips/household, yet show an insignificant difference between means.

Note that assessing the significance of the differences, statistically or intuitively, should be taken for what it is. The size of the sample by cell, the magnitude of the trip rate, and the proportion of trips by a market segment should also be considered as

TABLE 7

STATISTICAL ANALYSIS OF VARIATION IN AVERAGE TRIP RATES
1965 VS. 1981 REGIONAL WEEKDAY TRIPS BY PURPOSE AND MODE

Market Stratifier	Market Segment	1965 Survey			1981 Survey			Standard Error of Difference Between Means	t Score	Significant Difference?
		Mean	Standard Deviation	Standard Error of Mean	Mean	Standard Deviation	Standard Error of Mean			
TRIPS PER HOUSEHOLD										
Trip Purpose	HBW	1.858	1.774	0.012	1.890	1.876	0.024	0.026	1.23	no
	HBSH	2.731	3.716	0.076	2.274	2.778	0.035	0.051	8.96	yes
	HBSR	1.184	2.445	0.017	1.262	2.034	0.026	0.034	2.28	yes
	HBSK	1.097	2.280	0.016	0.952	1.883	0.024	0.032	4.56	yes
	HNB	1.906	3.481	0.024	2.335	3.225	0.041	0.050	8.65	yes
Trip Mode	Veh. Driver	4.534	4.549	0.032	5.231	4.765	0.060	0.067	10.46	yes
	In-Vehicle	6.535	6.981	0.049	6.814	6.237	0.079	0.099	2.83	yes
	Transit	0.486	1.071	0.007	0.558	2.028	0.026	0.020	3.67	yes
	Person	7.021	6.942	0.048	7.372	6.223	0.079	0.098	3.57	yes
	Total	8.777	8.129	0.057	8.713	7.091	0.090	0.114	0.56	no
TRIPS PER PERSON										
Trip Purpose	HBW	0.595	0.709	0.005	0.737	0.806	0.010	0.011	3.77	yes
	HBSH	0.875	1.068	0.007	0.887	1.097	0.014	0.016	0.58	no
	HBSR	0.379	0.731	0.005	0.492	0.858	0.011	0.011	8.06	yes
	HBSK	0.351	0.480	0.003	0.371	0.481	0.006	0.007	16.82	yes
	HNB	0.610	1.212	0.008	0.911	1.506	0.019	0.019	11.80	yes
Trip Mode	Veh. Driver	1.452	1.681	0.012	2.041	2.074	0.026	0.026	22.84	yes
	In-Vehicle	2.092	2.074	0.014	2.658	2.369	0.030	0.031	18.20	yes
	Transit	0.156	0.461	0.003	0.218	0.858	0.011	0.008	7.40	yes
	Person	2.248	2.037	0.014	2.876	2.273	0.029	0.030	20.70	yes
	Total	2.810	2.172	0.015	3.399	2.531	0.032	0.033	13.98	yes

TABLE 8

STATISTICAL ANALYSIS OF VARIATION IN AVERAGE TRIP RATES
1965 VS. 1981 REGIONAL WEEKDAY TRIPS/HOUSEHOLD BY HOUSEHOLD STRATIFICATION

Market Stratifier	Market Segment	1965 Survey			1981 Survey			Standard Error of Difference Between Means	t Score	Significant Difference?
		Mean	Standard Deviation	Standard Error of Mean	Mean	Standard Deviation	Standard Error of Mean			
Number of Residents	1	3.335	2.860	0.057	3.953	3.222	0.080	0.096	6.46	yes
	2	6.169	4.623	0.060	7.079	5.045	0.111	0.121	7.51	yes
	3	8.443	5.822	0.094	9.646	6.279	0.196	0.208	5.78	yes
	4	11.309	7.868	0.128	13.533	7.209	0.246	0.293	7.60	yes
	5+	15.222	10.670	0.160	17.717	9.576	0.378	0.445	5.60	yes
Autos Available	0	3.912	4.341	0.096	3.996	4.716	0.146	0.170	0.50	no
	1	7.618	6.780	0.072	6.301	5.587	0.117	0.154	8.58	yes
	2	11.113	8.688	0.099	10.101	7.258	0.164	0.214	4.74	yes
	3	13.274	9.580	0.246	12.776	8.180	0.320	0.430	1.16	no
	4+	14.663	10.675	0.538	14.580	9.415	0.573	0.806	0.10	no
Structure Type	SFDU	10.131	8.709	0.071	10.196	7.850	0.136	0.164	0.40	no
	DUPLEX APT	6.128	5.050	0.159	7.362	6.316	0.291	0.316	1.57	no
			5.250	0.083	5.835	5.166	0.113	0.141	2.08	yes
Household Income	Low	5.925	6.153	0.090	5.992	5.364	0.135	0.174	0.39	no
	Medium	9.418	8.019	0.100	9.058	6.856	0.162	0.208	1.73	no
	High	11.590	8.953	0.109	11.886	7.586	0.189	0.241	1.23	no
	(Not Reporting)	6.403	6.591	0.126	7.207	7.235	0.206	0.234	3.44	yes
TOTAL		8.777	8.129	0.057	8.713	7.091	0.090	0.114	0.56	no

judgements are made about the change and in the use of rates for forecasting.

3.0 CHANGES IN AGGREGATE TRIP CHARACTERISTICS, 1960-1980

Aggregate data are area-wide estimates derived from expanded survey, expanded census or 100% counts. Aggregate trip characteristics discussed in this section represent average regional weekday travel. Their value lies in understanding the overall composition of the travel market or in data factoring. The data is referred to interchangeably as 1980/1981 travel. This is because the 1981 Survey is expanded to 1980 households and, therefore, it represents 1980 travel. The assumption is that the household trip-making characteristics did not change between 1980 and 1981.

3.1 Distribution of Trips by Trip Purpose and Mode

Table 9 gives the trip purpose shares by mode for the regional trips in the two surveys. Between 1965 and 1980, work trips hold their share of the market, social/recreation remain relatively stable, school trips drop their share, and non-home-based increase by the same amount that shopping trips decrease (5%). This shows similar signs of change as those observed earlier in the trip rate analysis.

By mode, the trip purpose shares fluctuate more than the total. The direction of shift between shopping and non-home-based is consistent across all modes except for mode "Other," where both trip purposes decline by share. This may be due to the small number of trips in this category. The most important change shown in Table 9 is in the public transportation mode. Of the total transit trips, work trip

TABLE 9
COMPARATIVE REGIONAL TRIP PURPOSE SHARES BY MODE OF TRAVEL
1965 VS. 1980

Mode of Travel	Home-Based				Non-Home-Based	Total
	Work	Shop	Soc/Rec	School		
Vehicle Driver	28.4% 26.4	35.3% 30.3	11.1% 11.2	2.3% 3.3	22.9% 28.9	100.0% 100.0
Vehicle Passenger	11.5 11.2	35.4 24.1	20.5 27.0	9.4 13.5	23.1 24.2	100.0 100.0
In-Vehicle Person	23.2 22.9	35.3 28.8	14.0 14.8	4.5 5.7	22.9 27.8	100.0 100.0
Transit	45.3 36.9	17.6 15.2	7.2 8.0	17.6 22.6	12.3 17.3	100.0 100.0
School Bus	- -	- -	- -	100.0 100.0	- -	100.0 100.0
Walk	6.6 7.6	21.2 18.9	13.1 14.3	38.1 28.7	20.9 30.5	100.0 100.0
Other	11.6 19.5	20.1 14.5	21.7 24.6	21.6 25.3	24.9 16.2	100.0 100.0
Total	21.2 21.7	31.1 26.1	13.5 14.5	12.5 10.9	21.7 26.8	100.0 100.0

Notes: The upper entry is the 1965 trip purpose share in percent. The lower entry is the 1980 trip purpose share in percent.

purpose share drops from 45% to 37%. All the other purposes increase their share, especially school and non-home-based.

Table 10 gives the regional modal shares for work trips from 1960 to 1981. Two estimates are shown for the 1965 and 1981 Surveys. Home-Based Work (HBW) is the traditional definition. Home-Based-Work Census-comparable (HWC) is an estimate which takes into consideration the modal components used in the 1980 Census. The census shares are from data in published reports (16, 17, 18). The data in Table 10 shows that in-vehicle person share to work increased by 6% from 1960 to 1970 and remained relatively stable to 1981. Transit shares were on the decline between 1960 and 1970, and remained stable between 1970 and 1980. Walk trip shares continue to decline since 1960. Mode "other" shares increased slightly between 1960 and 1980. The decrease in walk trip share is a sign of continued suburbanization in the region where residences are increasingly farther from jobs for the walk mode to hold its own.

Table 11 gives the modal percentage shares by trip purpose. In-vehicle person trip share increases moderately for all trip purposes except for school, which increases sharply. Transit work trip share shows a decline between 1965 and 1980 due to a decline in transit between 1960 and 1970. Non-work transit trip shares show an increase by a moderate amount except for school trips where the share doubles. The moderate increase in non-work transit shares are understated since the decline between 1960 and 1970 of work trip share (shown in Table 10) probably applies to non-work trips as well. This means that between 1970 and 1980, non-work trip

TABLE 10
COMPARATIVE REGIONAL MODAL SHARES FOR WORK TRIPS
1960 TO 1981

Mode of Travel to Work	1960 Census	1965 Survey		1970 Census	1980 Census	1981 Survey	
		HWC	HBW			HWC	HBW
Vehicle Driver	N/A	68.4%	69.2%	70.9%	71.3%	72.0%	73.0%
Vehicle Passenger	N/A	12.6	12.4	8.9	9.4	9.6	9.4
In-Vehicle Person	73.4	81.0	81.6	79.8	80.7	81.6	82.4
Transit	16.2	12.7	11.9	11.6	11.6	11.7	10.9
Walk	8.2	5.0	4.8	5.9	4.5	4.2	4.0
Other	2.3	1.3	1.6	2.8	3.2	2.5	2.6
Total Travelers	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Travelers	95.3	N/A	N/A	97.6	98.1	N/A	N/A
Worked at Home	4.7	N/A	N/A	2.4	1.9	N/A	N/A
Total Workers	100.0	N/A	N/A	100.0	100.0	N/A	N/A

Notes: HBW means Home-Based Work. HWC means home-based-work census-comparable. Modal Shares are given in percentages.

TABLE 11
COMPARATIVE REGIONAL MODAL SHARES BY TRIP PURPOSE
1965 VS. 1980/81

Mode of Travel	Home-Based				Non-Home-Based	Total
	Work	Shop	Soc/Rec	School		
Vehicle Driver	69.2%	58.5%	42.6%	9.7%	54.4%	51.7%
	73.0	69.6	46.3	18.2	64.7	60.0
Vehicle Passenger	12.4	25.9	34.7	17.2	24.3	22.8
	9.4	16.8	33.8	22.4	16.4	18.2
In-Vehicle Person	81.6	84.4	77.3	26.9	78.7	74.5
	82.4	86.4	80.1	40.6	81.1	78.2
Transit	11.9	3.1	3.0	7.8	3.2	5.5
	10.9	3.7	3.5	13.3	4.1	6.4
School Bus	-	-	-	13.3	-	1.7
	-	-	-	9.3	-	1.0
Walk	4.8	10.5	15.0	46.8	14.7	15.4
	4.0	8.3	11.3	30.0	13.0	11.4
Other	1.6	1.9	4.8	5.2	3.4	3.0
	2.7	1.6	5.0	6.8	1.8	3.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
	100.0	100.0	100.0	100.0	100.0	100.0

Notes: The upper entry is the 1965 modal share in percent. The lower entry is the 1981 modal share in percent.

shares have increased more than indicated by Table 11. Walk trip shares declined for all trip purposes. Mode "Other" share is stable for total trips.

Comparison of County transit shares (not reported here) shows that for total trips, all nine counties increased their transit share between 1965 and 1980. For work trips, the urban counties which had improvements in bus and rail service increased their transit share significantly. Taking all the above statistics together, it is reasonable to assume that transit is now absorbing more of the non-work trip market.

3.2 Car Occupancy by Trip Purpose

Car occupancy is an important variable for assessing trends and for converting auto person trips to vehicle trips. The use of such an average is predicated by the absence of reliable car occupancy models.

Table 12 shows comparative regional occupancies by trip purpose from 1965 to 1981. They are computed from aggregate data for vehicle driver and vehicle passenger modes. Between 1970 and 1980, work-trip car occupancies remain constant. Comparison of 1965 and 1970 data suggest that work-trip occupancies were on the decline in the decade of the 1960s. It is unfortunate that there is no data from the 1960 Census to verify this apparent declining trend.

For non-work trips, the data shows a decline in vehicle occupancies of 4% to 20%. The 20% decline in school trip occupancy may be due to a decline in school enrollments for grades 1 through 8. The students

TABLE 12
COMPARATIVE REGIONAL WEEKDAY CAR OCCUPANCIES BY TRIP PURPOSE

Trip Purpose	1965	1970	1980	1981
Home-Based Work	1.18	1.13	1.13	1.13
Home-Based Shop	1.44			1.24
Home-Based Soc./Rec.	1.81			1.73
Home-Based School	2.78			2.23
Non-Home-Based	1.45			1.25
Total	1.44			1.30

in these grades are a potential market for carpooling (children driven) to school. Another factor at play here is the increase in college enrollments, a potential low car occupancy group for school trips.

The decline in shopping and non-home-based car occupancies may be due to the combined effect of a decrease in household size and the making of less home-based trips in favor of more non-home-based trips. Obviously the fewer household members in the decade of the 1970s relative to the 1960s, the lower car occupancy for home-based shopping trips. As more trips are combined into multi-leg tours, there is less of a chance for carrying passengers to the diversified activities conducted in non-home-based locations.

It should be pointed out that aggregate regional data does not necessarily reflect specific corridor or local highway car occupancies. Whereas the average occupancies may be stable or declining, major-corridor occupancies are on the increase for peak commute periods in the San Francisco Bay Area.

3.3 Reported Trip Duration by Trip Purpose and Mode

In both the 1965 and the 1981 Surveys, respondents were asked to record the times at the beginning and at the end of their trips. The resulting door-to-door one-way trip times are summarized in Table 13. The changes in trip duration are very minor for total trip purposes or total modes. By purpose, work trips are longest and shopping trips are shortest. By mode, transit trips are longer in 1981 than in 1965 by about 5 to 8 minutes for work, shop, school, and non-home-based trips. Social/recreation transit trip lengths are longer by about 14 minutes. This is an indication that residents of the region are using available transit to farther destinations relative to 1965.

The trip length frequency distributions by purpose and mode were also compared and found to be quite similar. The distributions were not smooth but had kinks at five minute intervals for all trip purposes. This is a well known phenomena where respondents tend to report the times to the nearest five minutes. Because of this, smooth network travel times are used in most travel demand analyses instead of survey-reported travel times.

The 1980 Census data shows that the average regional home-to-work

TABLE 13
COMPARATIVE REGIONAL REPORTED TRIP DURATION BY PURPOSE AND MODE
1965 VS. 1981

Mode of Travel	Home-Based				Non-Home-Based	Total Purposes
	Work	Shop	Soc/Rec	School		
Vehicle Driver	24	14	21	23	16	18
	24	14	19	20	16	18
In-Vehicle Person	24	15	20	17	16	18
	25	15	19	17	16	18
Transit	45	39	44	36	34	41
	50	44	58	42	42	47
School Bus	-	-	-	26	-	26
	-	-	-	29	-	29
Walk	13	13	14	15	12	14
	12	13	13	14	11	13
Other	18	11	13	12	8	12
	17	13	17	14	18	16
Total Modes	26	15	20	19	16	19
	27	15	19	21	17	19

Notes: Upper entry is for 1965. Lower entry is for 1981. All entries are in minutes.

trip length is 24 minutes (18). The 1981 home-based-work trip length from Table 13 is 27 minutes, 13% higher than the Census. Due to the differences between sample sizes and definitions, the 1981 estimate may not be unreasonable. What appears questionable is the constant trip duration for vehicle driver and in-vehicle person for work trips. Intuitively, we know that congestion has increased since 1965 and should have surfaced in longer trip lengths.

4.0 SUMMARY AND CONCLUSIONS

Updating large scale old home interview travel surveys with a small sample is worthwhile. It provides up-to-date information, comparative trip characteristics for investigating changes over time, and valuable data sets for disaggregate model development.

Household trip rates were found to be constant for total weekday trips. However, a shift has occurred between trip purposes: households made less home-based shopping/personal business trips, and more non-home-based trips in 1981 relative to 1965. This is an indication that the frequent home-based trips are being combined into multi-leg tours, thus increasing the number of non-home-based trips.

Household trip rates by socio-economic stratifications have undergone some change. However, due to shifts in the distribution of households by socio-economic stratifications, changes for the average regional household are much less.

Regionwide, work-trip transit share from the 1981 Survey was the same as that reported in the 1980 Census journey-to-work. This share declined

between 1960 and 1970. Between 1970 and 1980, the regional transit share was constant, but increased in those counties where transit service improvements were introduced.

Between 1965 and 1981, transit shares for non-work trips increased for every county. The statistics suggest that public transportation is now absorbing more of the non-work travel market relative to 1965.

Regional trip length frequency distributions reported by the respondents in the two surveys were found to be grouped into five-minute intervals. The changes in regional trip lengths between 1965 and 1981 were negligible.

Average regional car occupancies for work trips declined in the decade of the 1960s, and remained stable in the 1970s. For non-work trips, average occupancies declined between 1965 and 1981 due to changes in household size and combining of trips into multi-leg tours.

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